Non-resonant new physics using top-quarks

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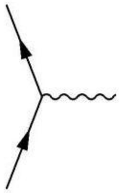
13 April 2011, Portoroz

C.D., J.-M. Gérard, F. Maltoni and C. Grojean and G. Servant(CERN), JHEP03(2011)125, [arXiv:1010.6304]

Outline

Effective theories

Direct production

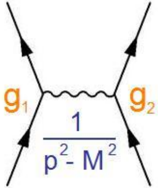


$s > \Lambda^2$

$\Lambda = M$

Effective theories

Off-shell contribution



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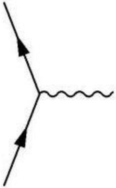

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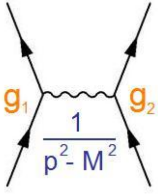

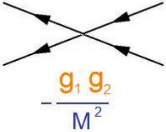

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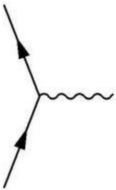


$s < \Lambda^2 \;\longrightarrow\; \frac{s}{\Lambda^2}$

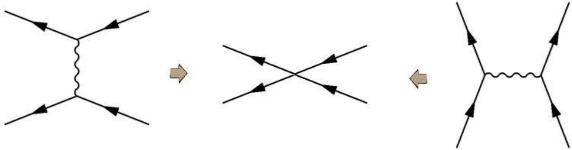
$s > \Lambda^2$

$\Lambda = M$

Motivations

Effective approach :

- Describes a large class of models



- The new interaction is strong (Composite models)
- Only new interactions allowed by the SM symmetries

Top-philic : top mass

- Large coupling with the EWSB sector
- $s \gtrsim m_t^2 \Rightarrow \frac{s}{\Lambda^2} \not\approx 0$ if $\Lambda \gtrsim 1$ TeV

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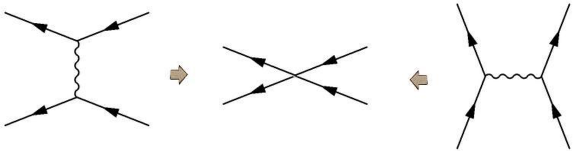

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The effective Lagrangian

Construction of the Lagrangian:

1. First order in the $\frac{1}{\Lambda}$ $\Rightarrow$ dimension six operators.
2. Interference with the SM (QCD process)

$$|M|^2 = |M_{SM}|^2 + 2\Re\left(M_{SM}M^*_{dim6}\right) + \mathcal{O}\left(\Lambda^{-4}\right)$$

$\Rightarrow$ new operators contain gluon, light quarks and top quarks.

3. Top-philic $\Rightarrow$ each operator contains at least one top quark.

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$$\mathcal{L}_{t\bar{t}} = \mathcal{L}^{SM}_{t\bar{t}} + \frac{1}{\Lambda^2}\Big(\left(c_{hg}\mathcal{O}_{hg} + h.c.\right)$$

$$+ \left(c_{R\,v}\mathcal{O}_{R\,v} + c_{R\,a}\mathcal{O}_{R\,a} + c'_{Rr}\mathcal{O}'_{Rr} + R \leftrightarrow L\right) + c^{(8,3)}_{Qq}\mathcal{O}^{(8,3)}_{Qq}\Big)$$

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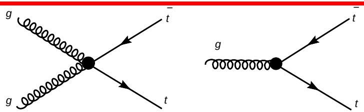

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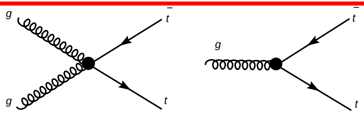

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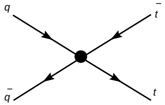

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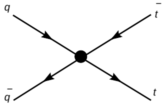

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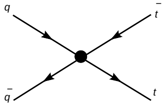

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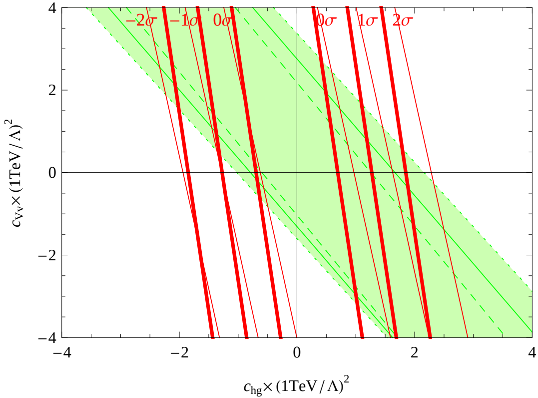
Total cross-section



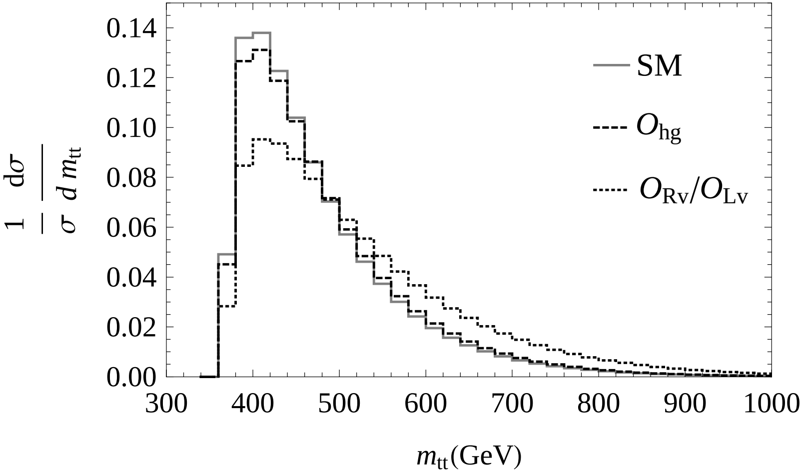
$$c_{Vv} = c_{Rv} + c_{Lv}$$

$$\sigma_{obs}^{14\,TeV} = \sigma^{NLO} \pm 10\%$$

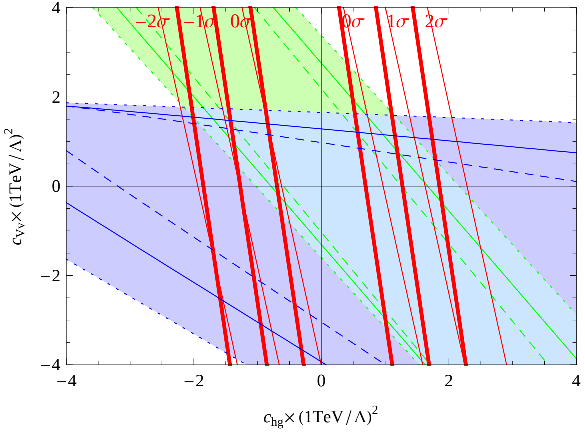
$$\sigma_{\text{obs}}^{1.96\text{ TeV}} = 7.5 \pm 0.31(\text{stat}) \pm 0.34(\text{syst}) \pm 0.15(\text{lumi})\text{ pb}$$

$$\sigma_{\text{obs}}^{7\text{ TeV}} = 158 \pm 10(\text{stat}) \pm 15(\text{syst}) \pm 6(\text{lumi})\text{ pb}$$

Invariant mass distribution (at the Tevatron)



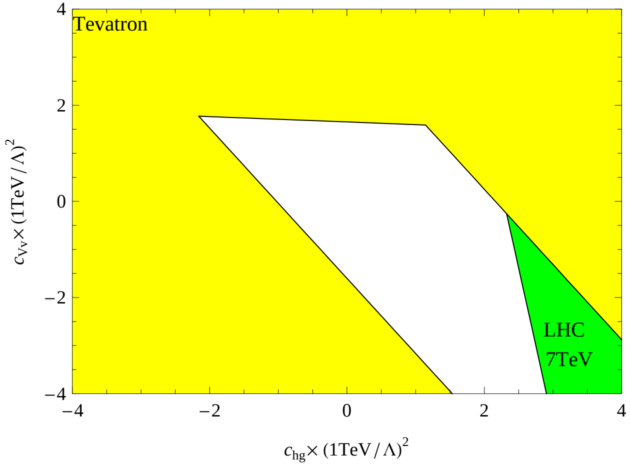
Invariant mass constraints



4.8 fb^{-1}

CDF Collaboration, *N. Goldschmidt, Search for T-Tbar Resonances at the Tevatron*, Proceedings of Science (2010), Talk 35th ICHEP.

Cross section and invariant mass constraints



Forward-backward asymmetry

The forward-backward asymmetry measured at the Tevatron,

$$A_{obs}\,(M_{tt} \geq 450\,\text{GeV}) = 0.475 \pm 0.114$$

is about 3σ away from the SM value,

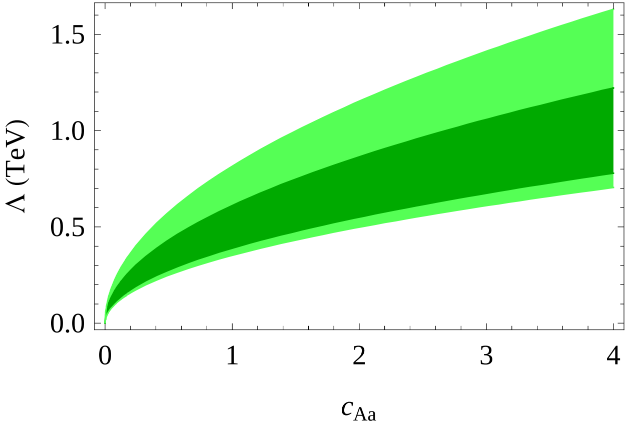
$$A_{SM}\,(M_{tt} \geq 450\,\text{GeV}) = 0.088 \pm 0.013.$$

From the effective Lagrangian, we obtain

$$\delta A\,(M_{tt} \geq 450\,\text{GeV}) = 0.087^{+10}_{-9} c_{Aa} \left(\frac{1\,\text{TeV}}{\Lambda}\right)^2$$

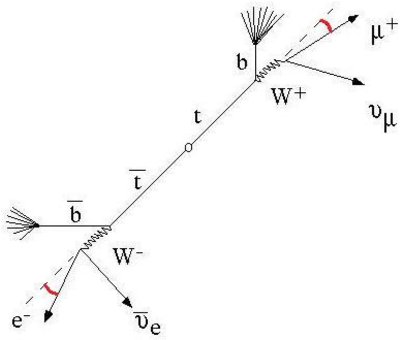
where $c_{Aa} = c_{Ra} - c_{La}$

With the invariant mass cut



Spin correlations at the LHC

$$\frac{1}{\sigma}\frac{d\sigma}{d\cos\theta_+ d\cos\theta_-} = \frac{1}{4}\left(1 + C\cos\theta_+\cos\theta_- + b_+\cos\theta_+ + b_-\cos\theta_-\right)$$

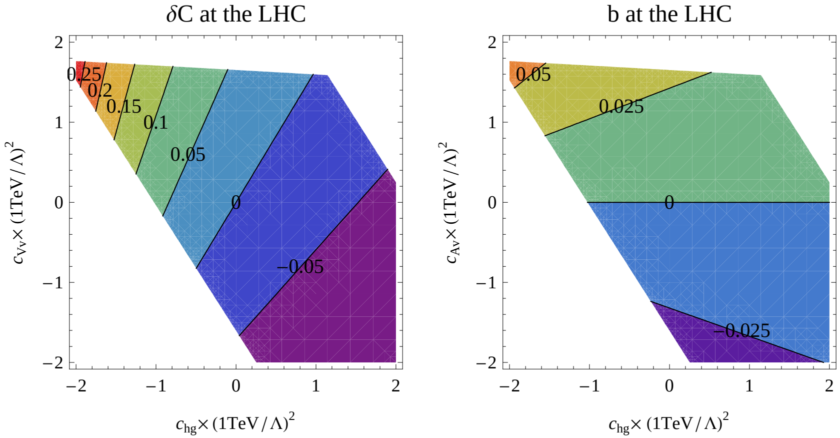


In the helicity basis,

$$\begin{aligned} C &= \frac{1}{\sigma}\left(\sigma_{RL} + \sigma_{LR} - \sigma_{RR} - \sigma_{LL}\right), \\ b_+ &= \frac{1}{\sigma}\left(\sigma_{RL} - \sigma_{LR} + \sigma_{RR} - \sigma_{LL}\right), \\ b_- &= \frac{1}{\sigma}\left(\sigma_{RL} - \sigma_{LR} - \sigma_{RR} + \sigma_{LL}\right). \end{aligned}$$

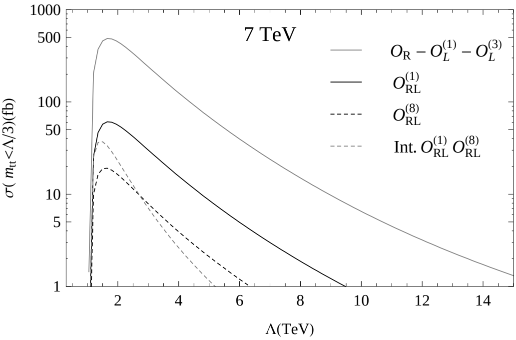
Spin correlation at the LHC

$$c_{Av} = c_{Rv} - c_{Lv}$$



Remark

Since uu is more likely than $u\bar{u}$ at the LHC, tt is more sensitive to four-fermion operators (arXiv:1104.1798).



Conclusion

- Effective theory is a model independent approach for new physics (available for exp.)
- c_{hg}, c_{Vv} are already be constrained by Tevatron and LHC cross-section and invariant mass distribution (Complementarity)
- A_{FB} can be explained if $c_{Aa} \sim 1$ and $\Lambda \sim 1$ TeV
- Spin correlation can be used to distinguish left and right handed top

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